Engineering and Scientific International Journal (ESIJ)
Volume 9, Issue 3, July – September 2022
ISSN 2394-7187(Online)
ISSN 2394 - 7179 (Print)

Catalytic Reduction of Carbon Dioxide -A Way to Reduce Enhanced Greenhouse Effect and Global Warming and Improve Climate Control

Mylaudy Dr. S. Rajadurai[1], Fatima Rajadurai[2]
Rajadurai Innovations, Chennai, India

Abstract — The uncontrolled natural calamities and catastrophes are frequently occurring due to climate change caused by global warming. The rapid increasing of carbon dioxide percentage in the atmosphere has been identified as one of the major contributors for the enhanced greenhouse effect, global warming and climate change. The amount of carbon dioxide produced from burning of fossil fuels is approximately 65%, which is more than any other sources of carbon dioxide emission. Also, it causes unstable thermal equilibrium in Earth and affects living organisms. Catalytic reduction of carbon dioxide using different catalysts are attempted to reduce carbon dioxide from internal combustion engine. Catalyst such as ZSM-5 Zeolite, activated wood charcoal, ZnO loaded activated charcoal, KOH loaded activated charcoal, activated alumina, charcoal derived from coconut raw materials and lithium silicate coated honeycomb reactor are tested on diesel and gasoline engines and the results are compared. Both absorption and adsorption takes place during CO2 reduction. Conversion vary from less 10% to more than 50% on different materials with different porosity and acidic sites. Modified synthetic materials with mega pores will be used to get more reduction of CO2.

Keywords — *Enhanced Greenhouse Effect; Global Warming; Climate Change; Catalytic Reduction of CO_2.*

1. Introduction

Enhanced CO2 is a very big challenge we are faced with today. The impact of CO2 on human health can be in differently extended starting from minor shortness of breath to fatal death. We need to exchange our manner of questioning and seeing things. The attention of oxygen in air is set 500 times better than CO2, but oxygen is ready 50 times less soluble. For both gases the awareness is decrease at higher temperatures. As the temperature boom the provision of CO2 decreases quicker than that of oxygen.

Natural calamities and catastrophes are frequently occurring due to climate change caused by global warming. Greenhouse effect changes the environmental climate and pollutes the green world. Also, it causes unstable thermal equilibrium in Earth and affects living organisms. Everyone in the world needs a world with the climate should be normal (i.e. world which is not too hot or too cool), but no one wants to pay or sacrifices to change our dependence on automobiles, plastics, etc. Slowing or maybe reversing the present fashion of worldwide warming is the defining task of a while Carbon is necessary for life, all living organisms contain carbon. CO_2 is a gas at standard temperature and pressure exists in Earth's atmosphere.

The infrared radiation arriving from Sun to the Earth is absorbed by greenhouse gases and emitted back as heat to maintain thermal equilibrium in the Earth's atmosphere (Figure:1). This natural process is termed as Greenhouse Effect. The major greenhouse gases are water vapor about 36-70%, carbon dioxide (CO_2) about 9-26%, methane (CH_4) about 4-9%, and ozone (O_3) about 3-7%. CO_2 among the greenhouse gases plays a vital role to maintain the temperature of the earth, without them the planet would be as cold as to be uninhabitable. However, the increased carbon dioxide concentration in the atmosphere must be harmful.

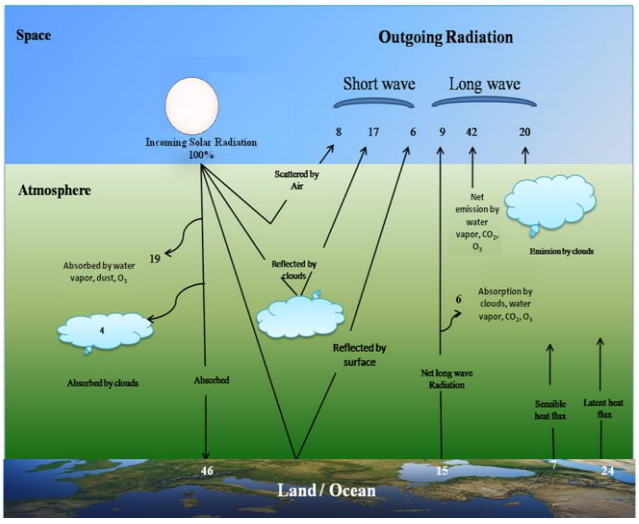

Fig.1: Stable Thermal Equilibrium in the Earth's Atmosphere

CO_2 in the atmosphere is naturally controlled by respiration of plants and animals, decay of plants and animals matter, burning of fossil fuels, deforestation and various industrial production processes. Since the industrial revolution (about 1760), global atmospheric concentrations of CO_2 have increased by 43% approximately. The majority of scientists agree that the level of carbon dioxide in the atmosphere is rising significantly as a direct result of human activities such as deforestation and fossil fuel combustion. This significant increase causes severe impact on human being directly and indirectly.

DOI: **10.30726/esij/v9.i3.2022.93004**

ISSN 2394-7187(Online)
ISSN 2394 - 7179 (Print)

2. Impacts of CO_2

The increasing emission of CO_2 and the disappearing carbon fixers has created serious disruption in the carbon balance in nature. This resulted to the gradual but recently exponential rate of accumulation of the greenhouse gases in the atmosphere and causes the impacts in environment, human health and society.

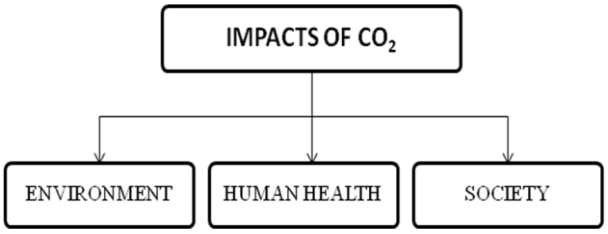

Fig.2: Impacts of CO_2

2.1 Impacts of Carbon Dioxide in Environment

The increasing CO_2 in atmosphere causes serious effects in environment in several ways. Some of them are:

- Environmental Pollution
- Acid Rain
- Enhanced Green House Effect
- Global Warming
- Climate Change

2.1.1 Environmental Pollution

Environmental pollutants is a totally big project we're facing today. It threatens the fitness of people and different residing things on our planet. It is able to be in particular dangerous to human beings with current lung or heart disease, the aged and the very younger. Air pollutants known as "air toxics" are recognized or suspected to motive cancer and different extreme fitness effects, inclusive of harm to respiration or frightened structures. Air toxics encompass metals, debris, and positive vapors from fuels and other sources. Global health organisation (WHO) anticipated approximately 800,000 human beings die consistent with 12 months due to best particle depend inhalation.

Environmental pollution are caused by CO_2 from sources like industrial smoke stacks, chemical plants, automobiles, gasoline stations, dry-cleaners, outboard motors, farm and construction equipment engines, certain paints and various household products.

2.1.2 Acid Rain

Carbon dioxide is a contributor to the environmental effect known as acid rain. Acid rain is precipitation containing harmful amounts of nitric and sulfuric acids formed primarily by sulfur dioxide and nitrogen oxides released by emission from fossil fuel-burning combined with moisture in the air into the atmosphere which causes physical damage to trees and other plant life due to high acid content. Water and soil pollution can also occur from the acidic precipitation. A complicating factor is the mobility of emissions. The effects of carbon dioxide can be seen and felt far from their sources, making their impacts on environmental pollution more serious.

2.1.3 Enhanced Green House Effect

The excess of CO_2 in atmosphere prevents the escaping of heat waves away from earth's surface and it causes a gap in the ozone layer. The ozone layer protects the earth's atmosphere from harmful rays produced from the sun. The influence of methane and CFC are very high though they are present in lower quantities but water vapor dominates the greenhouse effect among the contributing gases. CO_2 plays a major role in it because it increases the concentration of water vapor in air. If the percentage of carbon dioxide in air increases it will reduce oxygen concentration and it sensitizes myocardium to externally administered catecholamine. CFC's are mostly produced by the usage of refrigerants, aerosol propellants and cleaning solvents. These are some of the contribution to greenhouse gases caused by human which results the enhanced greenhouse effect as shown in figure2.

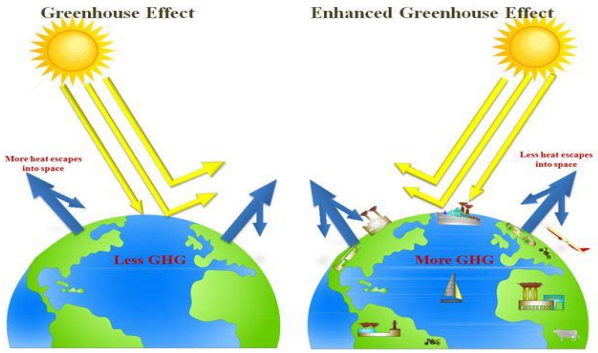

Fig.3: Enhanced Greenhouse Effect

2.1.4 Global Warming

The earth average atmosphere temperature must be maintained at approximately 600F conductive to life. The excess of heat waves trapped in earth's surface due to enhanced greenhouse effect causes in global warming. Global warming is the main contributor for environmental climate change. The impacts of global warming are being felt across the globe. According to studies done by the National Oceanic and Atmospheric Administration (NOAA), the earth's surface temperature has risen over the last 100 years. Excessive warmth waves have triggered tens

DOI: **10.30726/esij/v9.i3.2022.93004**

ISSN 2394-7187(Online)
ISSN 2394 - 7179 (Print)

of heaps of deaths around the arena in current years. The earth's ocean temperatures are getting warmer too.

Rate of global average sea level has risen from 1.8 mm/year to 3.1mm/year from 1961 to 1993. The reasons for sea level rise have been due to thermal expansion, melting glaciers, ice caps and the polar ice sheets. The prolonged periods of high temperatures in some regions, contribute to conditions that lead to larger wildfires and longer fire seasons. Global warming threatens the existence of life on this planet.

2.1.5 Climate Change

Another environmental impact of carbon dioxide is climate change. Weather exchange is a critical risk to anywhere. The effects of weather trade are relatively complicated. Scientists agree that the earth's growing temperatures are fueling longer and warmer warmness waves, greater common droughts, heavier rainfall, and extra effective hurricanes. For coastal communities, sea degree upward thrust, mixed with coastal storms, has improved the risk of erosion, typhoon surge damage and flooding. excessive heat, sea degree upward thrust, and heavy downpours are affecting infrastructure like roads, rail strains, airports, port centers, electricity infrastructure and army bases. From polar bears inside the Arctic to marine turtles off the coast of Africa, our planet's diversity of life is at threat from the changing weather.

2.2 Impacts of Carbon Dioxide in Human Health

Carbon dioxide is vital for internal breathing in a human body. Inner respiration is a method, through which oxygen is transported to frame tissues and carbon dioxide is carried far away from them. Carbon dioxide is a mum or dad of the pH of the blood that is vital for survival. The buffer device in which carbon dioxide performs an important role is called carbonate buffer. Its miles made of bicarbonate ions and dissolved carbon dioxide, with carbonic acid. The carbonic acid can neutralize hydroxide ions, which could growth the pH of the blood whilst brought. The carbonic acid can neutralize hydrogen ions, which would lower within the pH of the blood whilst brought. Each growing and reducing pH is life threatening. Other than being an critical buffer in the human machine, carbon dioxide is likewise known to motive health outcomes via displacing oxygen in the environment. .

Breathing becomes more difficult as carbon dioxide levels rise. High concentration of carbon dioxide gas in the blood and tissues increases the cerebral blood flow & intracranial pressure that causes high blood-pressure, headache, hallucination, vomiting, asphyxiation, kidney damage or coma, irregular heartbeats or even death may occur. Carbon dioxide degrees can also moreover advise high levels of various risky air pollutants which consist of unstable herbal compounds which make contributions to indoor air pollutants.

2.3 Impacts of Carbon Dioxide in Society

The drastic climate change and global warming causes heavy droughts and water scarcities which impacts our society in direct and indirect way. Longer, more intense droughts threaten vegetation, herbal international and freshwater materials. Low food production because of drought reasons humans to consume plenty less that result in starvation, malnutrition, anemia, vulnerability, illnesses/contamination and deaths. Smooth water ranges and water discharge within the course of droughts are low, resulting in much less dilution in surroundings waters.

This means that the concentration of chemicals, nutrients and solid particles increases, and dissolved oxygen decreases. Farmers and those whose livelihoods are directly connected to land and water may have high stress levels or experience anxiety or depression. Suburban housing, declining of forest cover and farmlands increases the effect of global warming.

Global warming causes the melting of glaciers, is the greatest threat to polar bears. The impacts of this change are felt worst in the Arctic. Polar bears rely on sea ice to hunt and store energy, when food can be scarce. The melting sea ice causes the bears to spend longer periods without food and their health declines. Due to unhealthy bears, low reproduction rates and higher cub mortality are occurred, which will leads to extinction of polar bears. The main reason for death of the cubs are lack of food or lack of nursing mothers. The increasing earth's ocean temperatures causes projected sea level rise at the end of 21st century will be 18 to 59 cm. Soil erosion occurs due to sea level increase, results in loss of shoreline and coastal wetlands.

3. Need for Co_2 Control

Considerable amount of carbon dioxide (about 90 to 100 Pg) moves back and forth between the atmosphere and the oceans, and between the atmosphere and the land biosphere. Most of the CO_2 released in the air is stored either in the atmosphere or in the oceans. The oceans are able to hold much more carbon than the atmosphere (i.e., about 50 times more CO_2 than the atmosphere and 19 times more than the land biosphere) because most of the CO_2 that diffuses into the oceans reacts with the water to form carbonic acid, bicarbonate and carbonate ions effectively which reduces the CO_2 gas pressure in the water thereby allowing more diffusion from the atmosphere. But the continuous unbalanced production and reduction of CO_2 causes unstable thermal equilibrium and increases the residual CO_2 in the atmosphere (figure 3).

DOI: **10.30726/esij/v9.i3.2022.93004**

ISSN 2394-7187(Online)
ISSN 2394 - 7179 (Print)

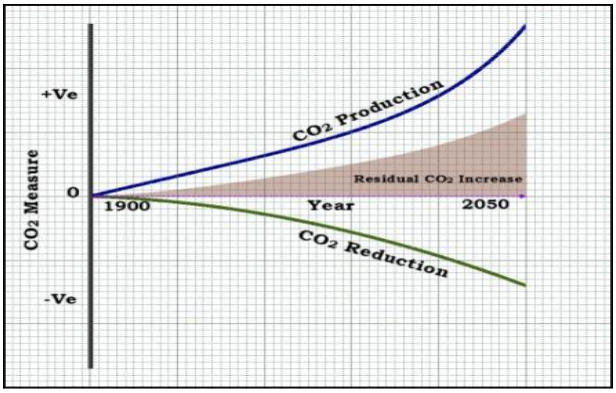

Fig.4: The continuous production and reduction of CO_2 in the atmosphere

This residual CO_2 increase in the atmosphere causes global warming, climate change which is a global challenge and it requires a solution. As the Earth gets warmer our entire ecosystems will shift and attains complete ecological change. The prime growing zones of crops are now threatened and many species of fish have migrated too long to stay in water at proper temperature for them. Figure 4 shows the gradual increase of global average temperature in recent years.

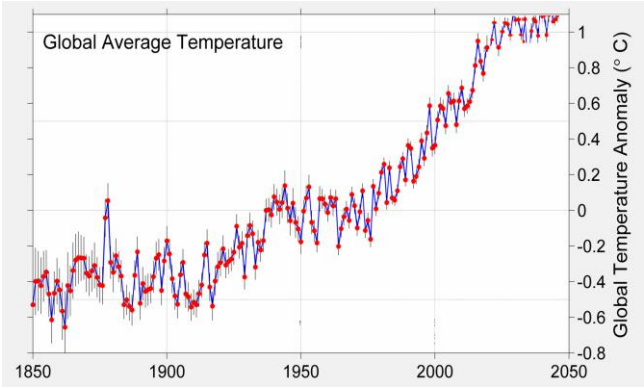

Fig.5: The gradual increase of global average temperature

The increasing temperature is responsible for the population rise of pest and also increases the reproduction rate of microbes and insects. The diseases caused by them are spreading all over the world which we are unable to develop a drug resistance to control it rapidly. So the need for CO_2 control is mandated.

4. Ways to Control CO_2

The increased CO_2 concentration in the atmosphere can be controlled in many ways of which three unique ways are:

a) Improving fuel efficiency in IC engine
b) Enriching Green development
c) Catalytic Reduction of CO_2

4.1 Improving Fuel Efficiency In IC Engine

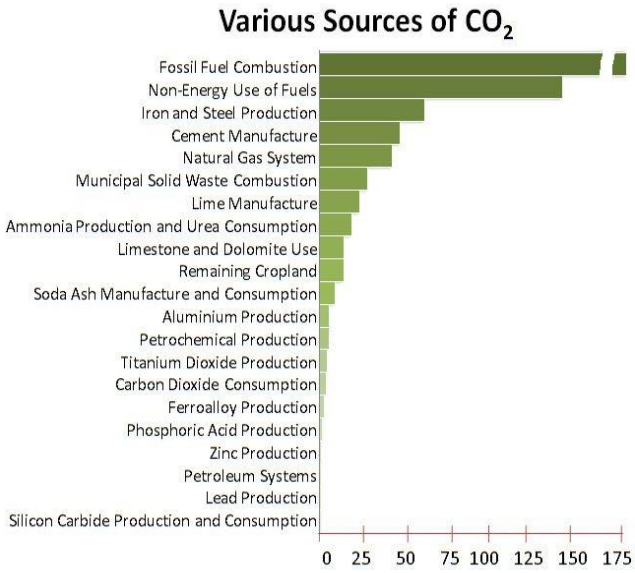

Fig.6: Various sources of CO_2

There are more than 20 sources of CO_2 production among which fossil fuel combustion is the largest sources of CO_2 productions as shown in figure 5. The engine out gas emitted as a result of combustion of fuels also emits other pollutants such as oxides of nitrogen (NO_X), carbon monoxide (CO) and un-burnt hydrocarbon (HC). These engine out gases are passed through the exhaust system into the atmosphere. Advancement in IC engine improves fuel efficiency and reduces the production of CO_2 and other pollutants. The exhaust after treatment system (EATS) is installed after the engine which is responsible for converting the harmful exhaust gases and reduces the exhaust emission into 95% before reaching the atmosphere thus production of CO_2 is substantially reduced.

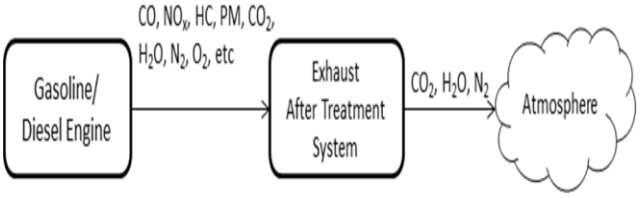

Fig.7: The working of exhaust after treatment system (EATS)

Reaction in EATS: $2\,CO + O_2 \rightarrow 2\,CO_2$

$2\,CyHn + (n/2 + 2y)\,O_2 \rightarrow 2y\,CO_2 + n\,H_2O$

$2\,NO + 2\,CO \rightarrow N_2 + 2\,\,CO_2$

4.2 Enriching Green Development

We can contribute to climate stability by simply planting more trees, which reduces carbon dioxide and reduces respiratory illnesses caused by enhanced CO_2 in the

DOI: **10.30726/esij/v9.i3.2022.93004**

ISSN 2394-7187(Online)
ISSN 2394 - 7179 (Print)

atmosphere. Hence a cleaner environment will contain less disease causing organisms and have a healthier population. The process in plants and algae by which atmospheric carbon dioxide is converted into organic carbon compounds, such as carbohydrates and sugar, is termed photosynthesis. The most important waste product of photosynthesis is oxygen which is ubiquitous for life on earth.

$$6\,CO_2 + 6\,H_2O \longrightarrow 6\,O_2 + C_6H_{12}O_6$$

Reaction: Photosynthesis dominates during the warmer part of the year i.e., CO_2 in the atmosphere will decreases during the growing season and respiration dominates during the colder part of the year. Some plants also help soil to capture significant amounts of carbon from air.

Hence planting more trees in an area as large as the size of the United States would cut atmospheric carbon dioxide by 25 percent and it also increases the Earth's forest cover. But it could take more than a hundred years to add enough mature forest to get sufficient levels of carbon reduction. Meanwhile 40 billion tons of carbon dioxide from burning fossil fuels are being added to the atmosphere every year. Figure 6 shows the production verses reduction of CO_2

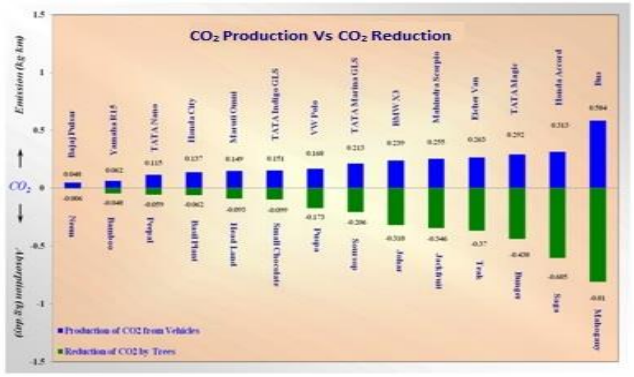

Fig.8: The production Vs reduction of CO_2

"The worldwide tree recuperation capability" report placed that there can be enough suitable land to increase the area's wooded area cover with the aid of 1-0.33 without affecting cutting-edge cities or agriculture. However, the amount of suitable land area for planting trees diminishes as global temperatures rise. Even if global warming is limited to 1.5°C from 2°C, the area available for forest restoration could be reduced by a fifth by 2050 because it would be too warm for some tropical forests. Hence more reduction of CO_2 is required.

4.3 Catalytic Reduction of CO_2

Automobiles are very much needed for day to day life, but it also plays a significant role of polluting the air in the atmosphere. A typical passenger vehicle emits about 4.6 metric tons of carbon dioxide per year (i.e.) 1 liter of Petrol produces 2.22 kg of CO_2 and 1 liter of Diesel produces 2.64 kg of CO_2. The control of CO_2 by enriching green development and by improving fuel efficiency in IC engines is displayed in figure 7.

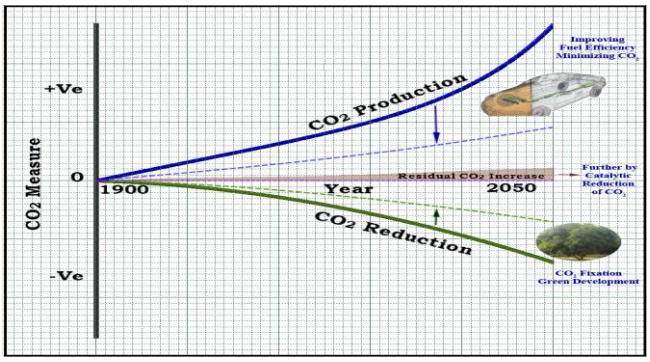

Fig.9: The need for catalytic reduction of CO_2

The control and reduction of CO_2 takes place at a very limited amount in the atmosphere. As seen in the figure there is still continuous residual enhancement of CO_2. This can be further reduced by catalytic reduction of CO_2.

In this paper, the catalytic reduction of CO_2 in automobile exhaust system is carried out on both gasoline and diesel engines. The mechanism of catalytic reduction of CO_2 is followed by absorption and adsorption processes. The catalytic reduction of CO_2 is done after the exhaust after treatment system (EATS) in the combustion engines to reduce the production of CO_2 in the atmosphere. The process of catalytic reduction of CO_2 for an engine is illustrated in the figure 8.

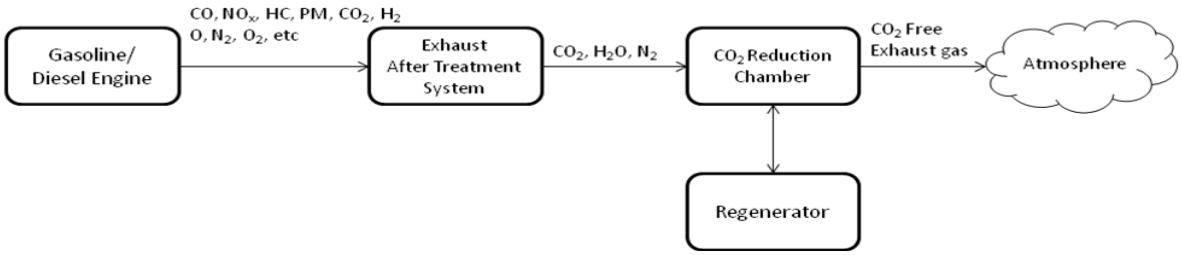

Fig.10: The process of catalytic reduction of CO_2

DOI: **10.30726/esij/v9.i3.2022.93004**

ISSN 2394-7187(Online)
ISSN 2394 - 7179 (Print)

The exhaust gas from exhaust after treatment system is passed through a fixed bed CO_2 catalytic reaction chamber. The test results have been analyzed and compared. A gas analyzer is also used to analyze the concentration of exhaust gases such as CO, CO_2, O_2, NO_X and HC.

4.3.1 CO_2 Reduction Chamber

The CO_2 reduction chamber is installed after the exhaust after treatment system in the tail pipe of the exhaust system. The CO_2 reduction chamber will absorb/adsorb the CO_2 and then it will dispatch CO_2 free exhaust gas into the atmosphere. The CO_2 reduction chamber is then regenerated. The reduction chamber is filled tightly with the CO_2 absorb/adsorb catalyst material. A model of CO_2 reduction chamber and the isometric view of CO_2 reduction chamber are shown in figure 9 and 10.

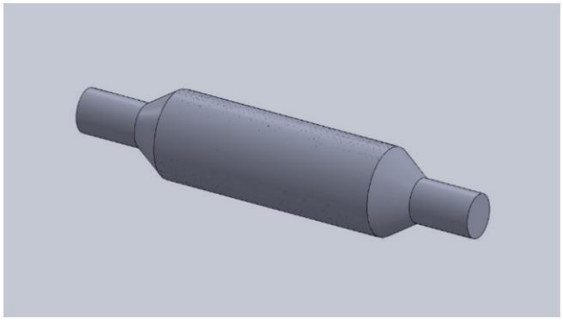

Fig.11: Model of CO_2 reduction chamber

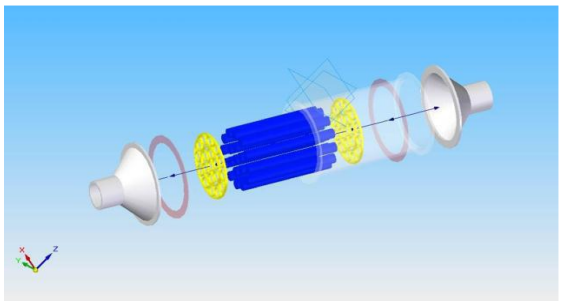

Fig.12: Isometric view of CO_2 reduction chamber

4.3.2 Catalyst used for Co_2 Reduction

High surface area porous support material conventional catalysts are used for CO_2 absorption. Both activated materials and catalyzed support materials containing Bronzted acid sites are preferred for CO2 adsorpion. The catalysts are used with and without activation. Here we have chosen support materials with varying porosity such as charcoal, alumina and Zeolite. They are mixed with the solution of Nano magnesium oxide and polyethylene glycol, zinc oxide (ZnO), potassium hydroxide (KOH) and are activated by being exposed to oxidizing atmospheres (carbon dioxide, oxygen, or steam) at temperatures above 250°C to form activated alumina, activated ZSM-5 Zeolite, activated charcoal from wood (activated wood charcoal A) and coconut shell (activated wood charcoal B), ZnO loaded activated charcoal (activated wood charcoal A) and KOH loaded activated charcoal (activated wood charcoal B). Wire Mesh is used to hold and prevents escaping of sorbents out of the reduction chamber due to abrasion. An example for wire mesh filled with catalyst and wire mesh loaded into the reduction chamber is shown in figure 11 and 12.

Fig.13: Wiremesh filled with Catalyst

Fig.14: Wire mesh loaded into the chamber

4.3.3 Engine Test Assembly For Co_2 Reduction Study

The EATS is installed after the engine which is responsible for converting the harmful exhaust gases and reduces the exhaust emission into 95% before reaching the atmosphere. The EATS contains oxidation catalyst, NOx after treatment system, PM (Particulate Matter) and HC control components.

Reaction in EATS:

$$2\,CO + O_2 \rightarrow 2\,CO_2$$
$$2\,CyHn + (n/2 + 2y)\,O_2 \rightarrow 2y\,CO_2 + n\,H_2O$$
$$2\,NO + 2\,CO \rightarrow N_2 + 2\,CO_2$$

The gas stream out of the exhaust after treatment system is passed through CO_2 catalytic reactor chamber. The pictorial representation of the CO_2 reactor chamber mounted on an engine is shown in figure 13.

DOI: **10.30726/esij/v9.i3.2022.93004**

ISSN 2394-7187(Online)
ISSN 2394 - 7179 (Print)

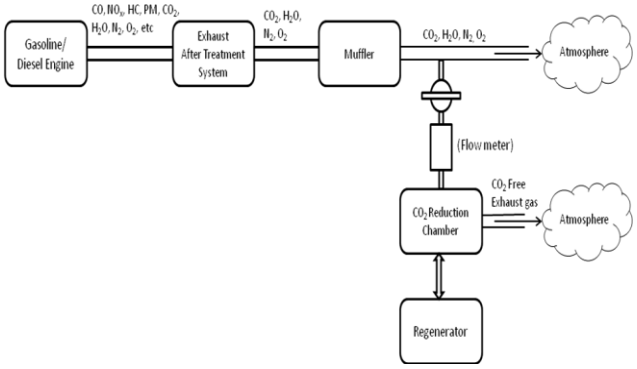

Fig.15: Representation of engine test assembly

Experiments were performed and a consistent quantity sampling technique is used to research the exhaust gasoline circulate. Consequences reproduced by using manner of repeated experiments below identical test conditions. Samples are taken before and after the catalytic CO_2 reduction chamber for quantitative measurement of CO_2 reduction.

4.3.4 Results and Summary

Table 1: CO_2 Reduction efficiency of different catalysts in diesel engine

CO_2 REDUCTION IN DIESEL ENGINE		
S.No.	Material	% of Reduction
1	MgO loaded activated alumina	3.3%
2	Activated wood charcoal A	9.8%
3	KOH loaded activated wood charcoal B	30%
4	Activated wood charcoal B	64%
5	ZnO loaded activated wood charcoal A	63%

Table 2: CO_2 Reduction Efficiency of Different Catalysts in Gasoline Engine

CO_2 REDUCTION IN GASOLINE ENGINE		
S.No.	Material	% of Reduction
1	Activated alumina	7.6%
2	Activated wood charcoal A	6.8%
3	Activated wood charcoal B	9.2%
4	Activated ZSM-5 Zeolite	52.3%
5	Lithium Silicate coated Honeycomb	21.4%

Table: 1&2 shows the substantial CO_2 reduction efficiency of catalysts may differ due to their physical characteristics (i.e.) low resident time for absorption caused by high mass flow rate of the engine. It is observed that the reduction efficiencies of CO_2 in both diesel and gasoline engine using activated alumina and charcoal derived from coconut raw materials are less than 10% due to low pore volume (or) lower surface area. The activated wood charcoal and ZnO loaded activated charcoal shows more catalytic adsorption efficiency in diesel engine than that of KOH loaded activated charcoal due to high porosity.

Chemical adsorption and catalytic reduction certainly is more efficient than mere physical absorption, as it is limited to physical nature of the catalyst. In order to differentiate physical absorption and catalytic adsorption, lithium silicate-coated honeycomb reactor is used in gasoline engine to reduce CO_2. The amount of lithium silicate layer coated on honeycomb is chosen in such a way that only chemical bonding and conversion occur and clathration & absorption cannot take place.

The lithium silicate coated honeycomb reactor shows approximately 21.4% of CO_2 reduction performance, which is relatively higher in the gasoline engine. This process of adsorption won't affect the increase in emission of other gases. Because of the adsorption process we are able to recycle the catalyst used and the adsorbed carbon dioxide may be carried out, so this device of adsorption will no longer affect the surroundings. Exhaust pipe coated with copper-zirconium alloy material can also be used to reduce the exhaust emission of carbon monoxide and carbon dioxide before leaking into the atmosphere, although its efficiency under real conditions is unknown.

5. Conclusion

Carbon dioxide is reduced by absorption as well as adsorption on the catalyzed materials. Charcoals show different conversions mainly due to different surface area and porosity of the materials. Absorption is more when the material is high porous whereas adsorption is more on acidic sites of the material specifically on Bronsted acidic sites. Zeolites with high surface area and porosity as well as Bronsted acidic sites show high reduction of CO2. KOH and ZnO coated charcoals also show high conversion due to preferential adsorption along with absorption. Catalyst coated honeycombs show low conversion mainly due to comparably low porosity. Alumina with low surface area and porosity as well as MgO coated alumina show very low reduction. It is confirmed materials with mega pores are required to give more reduction of CO2. We will attempt to reduce maximum CO2 using modified mega porous materials.

References

[1] Dr. S. Rajadurai, R.K. Anulatha, "Carbon Dioxide Fixation – The Must and the Path", International Journal of Science and Advanced Technology, Volume 2 No 5 May 2012

DOI: 10.30726/esij/v9.i3.2022.93004

ISSN 2394-7187(Online)
ISSN 2394 - 7179 (Print)

[2] Sivanandi Rajadurai and Prasanti Raveendran, "Environmental accountability for a sustainable Earth", Indian Journal of Science and Technology, Vol. 4 issue 3 (March 2011), 355-360.
[3] Mylaudy Dr. S Rajadurai, J. Maya, "Carbon Dioxide Reduction in Diesel Power Generator using Modified Charcoal", International Journal of Recent Development in Engineering and Technology, Volume 4, Issue 9, September 2015.
[4] S. Rajadurai, R.K Anulatha, "Catalytic Reduction of CO_2 in Gasoline Passenger Car", International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 8, October 2014
[5] https://warmheartworldwide.org/climate-change/, visited on 07.03.2022.
[6] https://www.nationalgeographic.com/environment/2019/07/how-to-erase-100-years-carbon-emissions-plant-trees/, visited on 07.03.2022.
[7] https://blogs.ei.columbia.edu/2018/11/27/carbon-dioxide-removal-climate-change/, visited on 08.03.2022.
[8] https://en.m.wikipedia.org/wiki, visited on 10.03.2022.
[9] https://www.changingwithclimate.info, visited on 11.03.2022.
[10] https://www.epa.gov/transportation-air-pollution-and-climate-change/carbon-pollution-transportation, visited on 07.03.2022.
[11] Can Removing Carbon From the Atmosphere Save Us from Climate Catastrophe files, https://news.climate.columbia.edu/2018/11/27/carbon-dioxide-removal-climate-change/, visited on 12.03.2022.
[12] https://www.hsph.harvard.edu/, visited on 09.03.2022.
[13] https://www.who.int/globalchange/ , visited on 12.03.2022.

DOI: **10.30726/esij/v9.i3.2022.93004**